LECTURES

ON

ELECTRICITY.

WALTER G. SMITH, M.D.

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PREFACE.

The following Lectures were delivered in the Adelaide Hospital, in the Winter Sessions of 1871-2, and '72-3. They were intended to convey to the students, in a simple and condensed form, a knowledge of the principles of using rightly a power which is daily becoming more firmly established as one of our most valued therapeutic agents.

In their present form they are reprinted, with slight alterations, from the "abstracts" which were published in the Irish Hospital Gazette for 1873; and make no pretention beyond supplying an introduction to the more elaborate treatises published in our own and other languages.

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CLINICAL USES OF ELECTRICITY.

LECTURE I.

THREE PRIMARY FORMS OF ELECTRICAL FORCE—(*a*) MAGNETISM, (*b*) STATIC OR FRICTIONAL ELECTRICITY, (*c*) DYNAMIC OR CURRENT ELECTRICITY—INDUCED ELECTRICITY—DEFINITION OF THE METHODS OF EMPLOYING ELECTRICITY IN MEDICINE, VIZ., FRANKLINISATION, GALVANISATION, AND FARADISATION—SKETCH OF THE HISTORY OF ELECTRO-THERAPEUTICS. ELECTRO-MEDICAL APPARATUS; FRANKLINIC ELECTRICITY BUT SELDOM NECESSARY—GALVANIC BATTERIES (*a*) *inconstant*, *e.g.*, VOLTAIC PILE, PULVERMACHER'S CHAINS, (*b*) *constant*, *e.g.*, DANIELL'S, GROVE'S, SMEE'S, LECLANCHE'S, &C.—TESTS OF THE ACTIVITY OF THE BATTERY.

IN the following Lectures we shall consider in a practical manner one of the most influential means we possess for the relief or cure of disease, and confining ourselves to a few of the salient aspects of the subject, will endeavour to sift out only what is essential and of primary importance. At the outset we have to inquire what are the forms or modes under which this all-pervading

power, electricity, declares itself. These are exhibited in the subjoined table, and it is very necessary to seize clearly the definitions of the fundamental terms which we shall have constant occasion to use.

TABLE I.

I. MAGNETISM, *i.e.*, the power of attracting iron.
   (*a.*) Natural magnets: Lode-stone$=Fe_3O_4$.
   (*b.*) Artificial magnets.
      1. *Permanent* steel magnets, which are magnetised by means of other magnets.
      2. *Temporary* soft-iron magnets, which are excited by a voltaic current circulating in an insulated coil of wire around them, = electro-magnets. The magnetism ceases immediately when the voltaic current is broken.

II. STATIC or FRICTIONAL ELECTRICITY: is accumulated upon the *surface* only of bodies. Its velocity =288,000 miles a second. Its application to therapeutics=FRANKLINISATION.

III. DYNAMIC or CURRENT ELECTRICITY: traverses the *substance* of bodies. Usual source is chemical action.
   (*a.*) Directly produced from chemical action, viz., *galvanism*, or *voltaic electricity*. Its velocity depends upon various circumstances; *e.g.*, it is about 112,000 miles per second in an aerial telegraph wire, and only 3,000 miles a second in the Atlantic cable. Its therapeutic application=GALVANISATION.

   Induction or Faradic currents:
   (*b.*) Induced in a coil of wire by a permanent steel magnet: *i.e.*, *magneto-electricity*.
   (*c.*) Induced in a coil of wire by a voltaic current: *i.e.*, *electro-magnetism*.

   The therapeutic application of either (*b*) or (*c* =FARADISATION.

   (*d.*) Thermo-electricity.
   (*e.*) *Animal* electricity.

Since the loose manner of using the terminology of medical electricity by the profession and the public has introduced much confusion, the definitions may be briefly recapitulated:—

Let *electrisation* be used to signify the employment of electricity in any form whatsoever; then the use of frictional electricity is designated *franklinisation; galvanisation* means the employment of a direct battery current, *i.e.*, from a number of cells; and *faradisation*, the employment of induction currents.

The history of electro-therapeutics is naturally connected with, and has advanced step by step with the discoveries in electricity. The origin of electricity we all know dated from the discovery of the electric excitability of amber or *electron*, about two and a half millenniums ago. But that remained an isolated fact in the history of electricity for about 2,000 years; and, although the magnet was known in Europe in the twelfth century, it was not till 1600 that the term "electricity" was used by an English physician of the Court of Elizabeth, Dr. Gilbert, of Colchester. Laying aside the ancient custom of subjecting patients to the influence of torpedoes or electric eels (although Duchenne relates a case of the cure of paralysis by discharges of a torpedo), and disregarding the use of pure mag-

netism, which was especially recommended in the middle of the eighteenth century, we have three important eras in the history of medical electricity which, as it happens, may be exactly marked out by *three centuries.*

The earliest era was of course that in which the first form of electricity, namely, frictional or static electricity, was discovered. It (*a*) began in the *seventeenth* century, when the first machine was made by Otto von Guericke, the inventor of the air-pump, in 1672. This machine consisted of a globe of sulphur turned by an enormous fly-wheel, excited by the friction of a cloth held in the operator's hand. There was no therapeutic use made of that discovery for nearly a century afterwards. The first therapeutic application was made by Kratzenstein, in 1744, who cured a paralysed finger by its means. The Leyden jar, or apparatus for condensing a large quantity of electricity on a small surface, was accidentally discovered in 1745, by Cuneus, in removing a flask of water which he was endeavouring to electrify. Franklin's celebrated kite experiment, as it is called, by which he established the identity of lightning and ordinary electricity, is only 120 years old, *i.e.*, in 1752. Within the last seven or eight years there has been an attempt made to revive the use of statical electricity in

medicine, by the introduction of a particular form of machine called Holtz's machine, which was invented in 1865, and has since been much recommended for use in medicine; but, on the whole, of late years, statical electricity has not held its ground as a therapeutic agent.

The (*b*) era of galvanisation begins in the *eighteenth* century. Galvani's celebrated discovery of the electrical action of the frog's muscles and nerves, and their excitability by metallic circuit, was made in 1786, though not published for some years later. The Voltaic pile—the foundation and origin of all the forms of battery now used—was invented in 1800, but it is the name of Remak which is inseparably bound up with the therapeutical study of this form of electricity.

The (*c*) era of Faradisation is still more modern in the *nineteenth* century. Faraday discovered induction currents in 1830. The first machine was made in 1831, and was of a very rude nature; and the investigator, whose name is most intimately connected with the therapeutical study of this form of electricity, is Duchenne, of Boulogne, whose researches, begun in 1847, have, though principally carried out in the preceding eight years, been continued down to the present time. Hence we see, that at first statical electricity was alone employed. Then galvanic

currents had their day. Next, for some years after Faraday's discoveries, induction currents played the principal part; and now the continuous current is being studied carefully side by side with induction electricity. All throughout, the history of medical electricity has been one of ups and downs, at one time extravagantly lauded, and at another as unduly depreciated.

We will turn our attention now to the apparatus by which these different forms of electricity are conducted to the patient's body, and there utilised. Since Franklinisation, or frictional electricity, is seldom used, it is sufficient to mention the mode in which it is recommended to be applied, either by what is called giving the patient an electric bath, *i.e.*, putting the patient on an insulating stool, in connection with the prime conductor of a machine, and so saturating him with positive or negative electricity as you choose, or by passing shocks to any part of the patient's body by means of a Leyden jar. There is no doubt that cures have been effected by this method, and, within recent years, some authors, as Russell Reynolds, and Duchenne, maintain the value of this form of electricity in certain cases, such as general tremor, facial neuralgia, and certain spasms. But, in consequence of the cumbrousness and other defects of the apparatus,

it is seldom employed. We shall, therefore, limit our attention to the methods of applying Galvanisation and Faradisation.

Galvanism is the medical employment of a voltaic current, the source of which is always chemical action. What is termed a ***simple circuit*** is the type of all batteries, and it is this: Any two ***dissimilar*** substances, such, for example, as copper and zinc, if immersed in any solution that will act ***more on one substance than the other***, will generate an electric current. The amount of electric energy set free is termed the "electromotive force" of the combination. A battery consists of two or more cells. If we connect the two poles of the battery by a wire, the circuit is said to be *closed*. If we disconnect them, the circuit is said to be *open*. What qualities, then, should a battery possess for medical purposes? It should plainly furnish a due quantity of electricity, be fairly constant in its action, be handy to use, and it should contain a sufficient number of cells to give it tension enough to overcome large external resistance.

A very simple division of the forms of galvanic batteries is into the two great classes of *inconstant* and *constant*, meaning by inconstant those in which the current rapidly diminishes in strength and regularity from the first setting

out, and by constant those which preserve a greater regularity of action. The reason why some are inconstant and others not is this: —All batteries are excited by some solution or another. The solution, of course, contains water. The water is decomposed by the electric current, and hydrogen and oxygen are evolved. The oxygen is liberated at the positive plate and attacks it, and the more inert hydrogen collects on the negative plate. Hence the electricity of the latter plate is neutralised, and "*polarisation*" of the plate is produced. Polarisation of the plates, that is the accumulation of hydrogen on the surface of one of the plates, is the main reason why certain batteries rapidly fail in power. Therefore, the principle of a constant battery must be to prevent the accumulation of hydrogen. The two principal types of inconstant batteries are what is termed the Voltaic pile and what are known as Pulvermacher's chains and belts. The Voltaic pile consists of a pile of alternate discs of zinc and copper, with cloth wet with vinegar between them. It is quite plain that every time electric action is developed it deteriorates in power, owing to exhaustion of the fluid and to polarisation, and hence it is almost universally given up. Within the last few years Dr. Hammond, of New York, has proposed a modified

form, consisting of perforated zinc and copper-plates, arranged in a particular way. But it has this inherent defect, that no matter how arranged its current must deteriorate. A very familiar form of inconstant battery is that known as Pulvermacher's chain, which consists simply of a portable Voltaic pile. But, even this, though it furnishes a high tension current for a short time, is very inconstant, sloppy to use, and cannot be depended upon. We have, therefore, inconstant batteries, such as Pulvermacher's, with very high tension, and very weak chemical action; and constant batteries, or those in which the accumulation of hydrogen is guarded against, and which accordingly possess a large amount of chemical power, but comparatively feeble tension, except with a number of cells.

The principle of all constant batteries is to prevent the accumulation of hydrogen, either mechanically, by facilitating its escape (*e.g.* Smee's), or chemically, by having in the cell some liquid which will chemically absorb the hydrogen and form a harmless compound (*e.g.* Bunsen's, Grove's, Daniell's, &c.) Daniell's battery is the most constant hitherto discovered and has been variously modified. It is extensively used for telegraph purposes, and largely for medical electricity in some of the Hospitals of *London.* A battery now being used very much,

not only for telegraphs, but also for medical purposes, is that known as the Leclanché battery, discovered in 1868; it consists of a zinc rod or plate, and of a porous cell, filled with charcoal, with or without black oxide of manganese, and is excited by being plunged in a solution of chloride of ammonium (sal ammoniac). It is comparatively inexpensive, very cleanly, gives off no acid fumes, is not corrosive if the fluid happens to be spilled, and it lasts for a long time with a single charge. It does not do for steady long-continued work, but it is never required for such purposes medically, and therefore it answers medical indications admirably.

Muirhead's modification of Daniell's battery furnishes a reliable current, but occupies a large space, and for convenience of reference, I subjoin a table contrasting it with the Leclanché battery.

LECLANCHE.	MUIRHEAD—DANIELL.
Electro-motive Force = 1·167 (Beetz.)	*Electro-motive Force* = 1.000.
More readily subject to polarisation; hence, it "strikes" after some time, and, therefore, is most suitable for short intermittent work.	Polarisation almost reduced to zero; hence, it is well suited for hard work continuously.
Extreme enduring power. Remains active for three and four years without recharging or cleaning. Will never refuse some amount of service, even after having been put away for years.	Requires frequent recharging and constant cleaning.

In all the ordinary kinds of battery, zinc forms one of the plates (generating plate), viz., the plate most acted on by the liquid, and the essential arrangement of the varieties of cell in daily use may be exhibited as follows. The wire connected with the zinc plate always form the negative pole.

Name.	Date	Plates.	Solution.	Elec-trom. Force.	Remarks.
Daniell..	1836	Zinc and Copper	Sulphate of Copper	470	Modified by Siemens and Halske (used on Continent); by Muirhead (used in England).
Grove ..	1839	Zinc and Platinum	Sulphuric and Nitric Acids	829	Too costly and troublesome for medical purposes.
Smee ..	1840	Zinc and Silver	Sulphuric Acid	210	Not well adapted for medical use.
Bunsen..	1843	Zinc and Carbon	Sulphuric and Nitric Acids	830	Modified by Stöhrer: Chromic instead of Nitric Acid.
Leclanché	1868	Zinc and Carbon	Sal-ammoniac	423	

It is necessary to be able to know whether your battery is in readiness for action or not, and this is very easily done. You could test it, of course, if you had a galvanometer; but there are two far simpler tests; one of these is to apply the current from three or four of the cells to your tongue, and notice whether you perceive a sharp metallic taste, and get a flash of light across your eyes, which is characteristic of this form of electricity. Another method is this:

electricity decomposes very rapidly iodide of potassium, liberating iodine at the positive pole, where it appears as a brown spot, and can be at once detected by starch.

LECTURE II.

ELECTRO-MEDICAL APPARATUS, CONTINUED—FARADIC (INDUCTION) MACHINES, (*a*) *Magneto-Electric*, *i.e.*, PRIMARY SOURCE OF POWER IS A STEEL MAGNET. (*b*) *Electro-Magnetic* (VOLTA-ELECTRIC), *i.e.*, PRIMARY SOURCE OF POWER IS A VOLTAIC OR GALVANIC CURRENT—DEMONSTRATION OF THE STRUCTURE OF A VOLTA-INDUCTION APPARATUS (INDUCTORIUM)—DEFINITION OF PRIMARY AND SECONDARY CURRENT—DIFFERENT FORMS OF INDUCTORIUM—MODES OF CONVEYING ELECTRICITY TO THE BODY; ELECTRODES (RHEOPHORES) FOR ORDINARY AND FOR SPECIAL PURPOSES—GENERAL EFFECTS OF ELECTRICITY:—(1.) *Physical* *e.g.*, LIGHT, HEAT, MAGNETISM, INDUCTION, &C. (2.) *Chemical*—OCCASIONALLY CAUSES COMBINATION, BUT MORE GENERALLY DECOMPOSITION—ELECTROLYSIS, DEFINITION OF, APPLICATIONS.

IN the preceding lecture, having explained the different forms of battery for furnishing a galvanic or voltaic current, and shown that a continuous current is not necessarily a constant current, let us now consider induction machines, or inductoriums, as they are called, which, briefly defined, are instruments for furnishing instantaneous currents induced in a metallic conductor by means either of a magnetic or of an electric current. Hence, we have two varieties of induc-

tion machines—the magneto-electric, in which the primary source of power is a magnet; and the electro-magnetic, in which the primary source of power is an electric current generated by chemical means. The special value of induction currents for medical purposes will be shown further on. One of the most convenient and neatest forms of magneto-electric battery has been brought out by Gaiffe. It consists essentially of three parts—a horseshoe magnet, placed in the back or side of the box; a coil of insulated wire; and a soft iron core in the centre of the coil. These are the three essential parts of every magneto-electric machine. By some mechanical means, such as a cogged wheel, or a revolving band, we cause the coil to rotate rapidly opposite the poles of the magnet, and at each approach to and recession from either pole, opposite currents are induced in the wire, chiefly by the rapid magnetisation and demagnetisation of the soft iron core. The physiological effects of demagnetisation are much more powerful than those of the current produced by magnetisation. Magneto-electric machines certainly recommend themselves by their comparative cheapness and their simplicity of construction; but the facts that they usually require an assistant to turn the handle, that the magnet gradually loses its power, the disagreeable

sensation experienced on applying the electrodes to the skin, and the circumstance that you can get all their good effects, and in a much superior degree, by volta-electric machines, justify the conclusion that magneto-electric machines may be altogether dispensed with in practice. We may, therefore, proceed with the explanation of what are termed electro-magnetic or volta-electric machines. These machines depend upon a threefold principle, viz. (1), that a voltaic current in one conductor can induce momentary currents in a separate and adjacent parallel wire; (2), that in a single coil of wire, traversed by a voltaic current, the superposed coils exercise an inducing action upon each other (*extra-current*); and (3), that an electro-magnet (*i.e.*, the *core*), induces currents in the surrounding coil of wire. The fundamental rule is, that the inducing current, *at the moment of its closure*, or making, induces a current in the *opposite* or inverse direction to its own; but, when *broken*, or interrupted, it induces a direct current in the *same* direction as itself. That is, induction currents are alternating and instantaneous.

There are six essential parts in a complete inductorium. The primary source of power is the electric current; therefore, there must be (*a*), a generating cell or cells. Some ma-

chines have only one, some have two. The variety of cell matters very little. In immediate connection with the generating cell is (*b*), what is called the primary coil, which is the central coil of all these machines. It is composed of short and comparatively thick wire, so as to offer as little resistance as possible to the passage of the feeble battery current. The *primary current* is the sum of the currents induced in this coil. (*c*), Surrounding this, but not touching it, is the secondary coil, which consists of a finer and much longer wire, the intensity of the induction depending largely on the length and fineness of this wire. The *secondary current* is the sum of the currents induced in this coil. In the axis of the primary coil there is always (*d*) what is termed a *core* of soft iron, made up of a bundle of iron wires. Surrounding either the core or the primary coil there is (*e*) what is called the graduating envelope. It must be composed of a non-magnetic metal, and is usually made of copper or brass. When the current is closed, the core of soft iron becomes an electro-magnet, and generates an additional electric current in the surrounding coils of wire. Therefore, the more powerfully the core is magnetised, the more powerful are the currents produced in the surrounding coils, and if the magnetism of the core

be diminished, you diminish its action on the coils; and accordingly, by the degree to which we cover or uncover the core in the primary coil we can regulate the inducing action of the core, and so graduate the current. In fact, when the core is surrounded by a non-magnetic metal, then the disappearing magnetism of the iron exerts its inducing action first on its metallic envelope, and not on the spiral. The most essential part of these machines is (*f*) what is termed the trembler or contact-breaker. Induction currents being instantaneous, are only produced at the moment the circuit is closed (*i.e.* made), or opened (*i.e.* broken). Therefore, we must have a means of interrupting the current with rapidity and regularity. In all the modern machines this is done by the trembler, which is a vibrating bar or pendulum of soft iron moving freely, and always placed in such a position to the magnetised core as to be attracted by it from its metallic contact, which completes the circuit, but the moment this is done the current is interrupted, the core loses its magnetism, and the trembler flies back by its own spring, remaking the contact, reproducing the magnetism, and thus it is alternately and rapidly attracted and set free. The rapidity of the interruptions is regulated by a screw, which acts on the trembler. As to the

forms of inductorium, one of the best and most complete, especially for Hospital use, is that manufactured by Stöhrer. Two forms of it, a larger and a smaller one, have been constructed. The larger machine is far the most satisfactory. The small bichromate inductoriums are also very serviceable. Quite recently, Mr. Yeates, of this city, has constructed for me an inductorium, worked, for the first time, by a Leclanché cell, which seems to fulfil every requirement of a convenient, reliable, and enduring instrument, and which will not need recharging for a long period. It is well adapted for country use. A small pocket apparatus, viz., the chloride of silver inductorium, has been brought out by Gaiffe, of Paris, each element of which is enclosed in a little box. It therefore cannot spill or leak, is handy and portable, but is apt occasionally to disappoint when wanted. But all small apparatuses have certain inherent objections. We cannot have too great a gain in space without sacrifice of some other desirable qualities. For example, a very small apparatus must necessarily have a small coil, which must be constructed of very fine wire, so that the current will be of high *density*. For medical purposes we never require a larger coil than that contained in Stöhrer's apparatus.

Before passing from the subject of electro-

medical apparatus, let me call your attention to one or two points of some significance. The choice of any particular induction apparatus is much less important than that of a good battery for the constant current, for, almost any of the former may be employed indifferently. It is far more essential that the physician should thoroughly comprehend the construction and management of whatever apparatus he adopts. In speaking of electric currents, it is very necessary to avoid the common error of confounding the terms *intensity* and *density*. The *intensity* of a current, is the quantity of electricity which passes through a conductor in a given time; it is directly proportional to the original electro-motive force of the cell or battery, whatever that be, and inversely as the resistance of the circuit. It is evident that a part of the electro-motive force must be spent in overcoming the resistance of the circuit. This is Ohm's law. But the *density* of a current depends further upon the diameter of the conductor, for, since the quantity of electricity which passes at a given time, through any part of a closed circuit (*i.e.* the intensity), is always the same, it is plain, that if a current of the same intensity be passed successfully through two conductors of the same material, one of which is, say, five times the diameter

of the other, its density will, in the latter case, be reduced to one-fifth, for it has to cover more ground. In other words, the density is directly as the intensity of the current, and inversely as the transverse section of the conductor. This holds only for good conductors, *e.g.* metals; with bad conductors, *e.g.* nerves, the density of the current does not change by augmentation of the section. The variations in the density of a current have much to do with the rational use of electricity in medicine. Again, it follows from Ohm's law that, for the excitation of nerve and muscle (on account of their enormous resistance compared with that of the battery), the *size* of the cells matters little, but a considerable *number* of cells is required. But when we employ electricity for galvano-caustic purposes in heating a short wire (*i.e.*, a small external resistance), we must increase the size of the cells, and not their number. From this we see that a clear appreciation of Ohm's law is essential to the electro-therapeutist.

We have now to consider the accessory apparatus, or the means of conveying electricity, furnished by any of these instruments, to the surface of the patient's body. The first essential is manifestly the insulating of the conducting wires. Yet, by some incomprehensible perverseness,

many of the machines, up to quite recently, were sent out with naked wires, so that if these crossed one another accidentally the current was neutralized before it reached the patient at all. The wires terminate in the electrodes, or rheophores, as they are sometimes called; or, in other words, the handles for applying the electricity to the surface, and these also should be fixed to insulating stems, such as wood or ebonite. The electrodes used for ordinary purposes are metallic cups, suitable for holding wet sponges; or metallic or charcoal knobs. But, plainly for special purposes, special electrodes are needed. For example, if we want to electrise the small muscles of the hand or face, a small pointed electrode, covered with chamois, is required. The most powerful means we have for exciting the cutaneous nerves is the electric brush. For electrising the larynx a very convenient and handy apparatus is that known as Mackenzie's laryngeal galvaniser, which is simply a piece of catheter tube traversed by a metal stem and put in connection with one pole of the battery, by depressing a lever on the handle, while the other pole is brought to the outside of the patient's neck. Obviously the same electrode can be used for application to the auditory meatus, &c. For applying electricity to the bladder, or to

the neck of the uterus, a very simple and convenient form is a piece of catheter tube similarly traversed by a metal stem, terminating in a metal head. For applying electricity to the large intestine, a very valuable means in some cases of constipation, a piece of enema-tubing traversed by a copper wire, and capped with a smooth brass head, may be employed.

The principal effects of electricity on the human body may be ranged under three heads—physical, chemical, and physiological. It is the latter class that most nearly concerns us, and which we shall take up in the next lecture; but before concluding I shall briefly draw your attention to one or two of the physical and chemical effects of electricity. The physical effects are production of light, and development of heat, magnetic effects, induction, and, a very singular one, what is called the mechanical transport of bodies. The electric light between the two metallic conductors of an ordinary frictional machine assumes very beautiful forms, either a long zigzag, or what is called the electric brush; but evidently light could never be expected to be manifested in living tissues, not only on account of the large surface which the body possesses, but also of the diffusion of electricity throughout the tissues. I may

mention a very ingenious application of electric light in illuminating the cavities of the body, by Geissler's tubes. Dr. Milliot proposes to introduce one of these tubes (*splanchnoscope*) up the rectum, so as to examine the interior of the patient's pelvis and abdomen. For various reasons, such as the unequal conductibility of the tissues, and the physical conditions of the parts, it is also impossible to measure the electric heat developed in the living tissues. But we can accurately measure it in metals; the worse the conductor, the more it is heated, the resistance to the passage of the current becoming transformed into heat. An important application of this fact is made in what is called the galvanic cautery, which simply consists of a wooden handle with two metallic stems running up to a little platinum point. Platinum being a bad conductor, a strong current sent through it generates heat enough to render the platinum tip red hot or white hot. This is applied, say in the case of a severe operation on the side of the face, to stop bleeding from a deep vessel. It is a most effectual means of cauterising deep parts, and has been used in various surgical operations. The only application we have of electric heat is in surgery.

A most remarkable effect of an electric current

is mechanical transport and disruption. The disruptive effects are seen in the destructive results of a flash of lightning. In the case of the electric light there is an actual transfer of particles from the positive to the negative pole, and it is easy to show experimentally that the laws of endosmose may be completely reversed by the passage of a continuous galvanic current. Accordingly, to relieve an œdema of the arm, Remak recommended to apply the positive pole on the œdematous part, and the negative pole on the healthy skin.

We will next advert to the chemical effects of electricity, which are twofold. Occasionally it causes a combination of simple gases, for example hydrogen and oxygen, which will explode and generate water; but, as a general rule, the chemical action of electricity tends towards producing decomposition. The varieties of decomposition may, for convenience, be arranged under these three heads, namely:—electrolysis, coagulation of b ood, and potential cauterisation. In relation to conduction, we may divide all bodies into two classes—first, simple bodies, such as metals which conduct electricity readily and suffer no alteration in their structure, except a rise in temperature; and, secondly, compound bodies, such as acidulated water, or other fluids,

which only conduct electricity in virtue of chemical decomposition. Electrolysis, or chemical decomposition of bodies, has received important applications in the treatment of tumors and other surgical diseases, and is especially applicable to fluid tumors. It has been very largely made use of on the Continent, and to some extent in these countries, especially by Dr. Althaus. There is no doubt that decomposition of even tolerably large tumors can be obtained by the persistent application of a continued current. Another important application of electricity is to the coagulation of blood, in the treatment of nævi, or small vascular tumors, and even of large internal aneurisms; for example, of the thoracic aorta on which it has recently been practised, with great boldness and gratifying success. Another application of electrolysis is to hydatid tumors of the liver, and indeed, the medical applications of electrolysis are attaining now very considerable importance. Lastly, remember that a galvanic current exercises a very decided cauterising effect upon the skin, and troublesome sores have frequently followed from the incautious, or too long-continued application of Pulvermacher's chains, or other forms of battery.

LECTURE III.

GENERAL EFFECTS OF ELECTRICITY, CONTINUED :—(3), *Physiological* OR VITAL EFFECTS, AS EXHIBITED IN *(a)* THE CIRCULATION, *(b)* THE MUSCULAR SYSTEM —DU BOIS REYMOND'S LAW; PFLUGER'S LAW; *(c)* THE NERVOUS SYSTEM—ACTION ON THE NERVE-CENTRES, THE NERVES OF SPECIAL SENSE, *e.g.*, THE RETINA—RELATIVE INFLUENCE OF THE + AND — POLE; *(d)* ON GENERAL NUTRITION. CONTRAST BETWEEN THE EFFECTS OF THE *direct* (CONTINUOUS, CONSTANT, OR GALVANIC) CURRENT, AND THE *induced* (INTERRUPTED, OR FARADIC) CURRENT.

AT the close of the last lecture we passed in review one or two of the important applications, especially of the chemical effects of electricity, and, in the present one, we shall briefly speak of the far more important physiological or vital effects on the living tissues of man, chiefly the muscular and nervous systems. The palpable effects of electricity will depend on two classes of conditions, first, those belonging to the electricity itself, for instance, its quantity, density, and the mode of transmission; and, secondly, those belonging to the organism itself; for example, the *kind of tissue acted* on, and its vital condition at

the time. The general action of electricity on any tissue may be considered to be, first, stimulant, and, secondly, alterative or modifying; but before proceeding to explain these effects, we should gain some idea of the facility of passage of electricity through the animal body. Is there a proper conductibility for every tissue in the body or not? Many discrepant statements have been circulated on this point, but the matter may be reduced to this: the conductibility of the body or any of its tissues depends mainly on the saline fluids contained in the part, and their degree of concentration, and not on the mere amount of water present. In fact, the whole body and its parts may be roughly viewed in relation to their capability of conduction, as a large cylinder of warm saline fluids, in which a number of tissues are suspended or imbedded, which have not among themselves very different degrees of conductibility. What we really want to know, however, is not the absolute conductibility of the different tissues, but only their relative resistances, upon which depends the intensity of the current which will traverse them; the greater the resistance, the less the intensity of the current. The dry epidermis offers enormously greater resistance than any other tissue in the body, and opposes the chief obstacle to the entrance of an

electric current. Copper is several thousand million times a better conductor than the body under ordinary circumstances. It has been calculated that the resistance of the whole body is equal to that of a copper wire a millimetre (·039 inch) in diameter, and between 200,000 and 300,000 feet in length.

This much premised, it may be said that the chief effect of electricity on the circulation is contraction, followed by dilatation. If a continuous galvanic battery current of ten or fifteen cells be passed through a paralysed limb, incapable of being warmed even by hot water, it often happens that the patient will soon experience a comfortable sense of warmth in it, and more will be done in that way to relieve the unpleasant feeling of coldness, and to promote the return of the natural circulation than by any other artificial means. But the more important effects of electricity are those on the nervo-muscular system, and especially on the motor nerves. Any form of electricity, whether static, voltaic, or induced, can excite muscles and nerves, and the two most important laws which govern this action, can be expressed in two formulas, which are the keystones of electro-therapeutics. Since the quantity of electricity furnished by a battery *is far greater* than that furnished by a large coil,

or by a frictional machine, it is necessary to inquire what relation the degree of muscular excitation has to the quantity of electricity. This is embodied in *Du Bois Reymond's law*, viz., a muscle or motor nerve is excited *not* by the absolute quantity of electricity, but by the *variations in intensity* of the electric current. From this we gather, first, that a perfectly continuous and constant current ought to have little or no action at all on muscles during its passage; and secondly, the more abrupt and rapid the variations (as in an induction coil) the more marked will the muscular contraction be. Strictly speaking, Du Bois Reymond's law should be formulated in a more general way, as has been done by Pflüger. The second law, which is a very important one, is known as *Pflüger's law of contraction*, and harmonises many of the discordant results previously taught. Let us make a rough division of electric currents into weak currents, currents of medium strength, and strong currents, premising that by *ascending* and *descending* currents—two terms constantly employed in medical electricity—we mean—ascending current, positive pole lowest down; descending current, positive pole highest up. Now, Pflüger's law teaches us that with weak currents contraction is obtained only at the closing of the circuit. If the current be stronger,

say of 20-30 cells, contraction is observed both on closing and opening the circuit; but, if it is a very strong current, say of 50-60 cells, contraction will appear only on opening the ascending current and closing the descending current. Therefore, as a practical result, if we wish by a battery current to produce muscular contraction, it is necessary to interrupt the current, because by Du Bois Reymond's law it is needful that there be variations in the intensity. In all cases, the negative pole causes greater irritation than the positive pole.

These laws show you that it is necessary to interrupt the current in order to get contraction; and, secondly, that the moment at which contraction occurs, will depend on the strength of the current. Rightly to apprehend Pflüger's law, it would be necessary to enter into the somewhat intricate subject of *electrotonus*, *i.e.*, the modifications in the irritability, and normal electric conditions of nerve and muscle, impressed by the passage of a continuous galvanic current. But this would lead us too far aside, and it is sufficient to state that the phenomena included in it have not only been established by experiments on the lower animals, but confirmed clinically *upon man.* The excitability of muscles and *nerves varies* considerably in different parts of

the body, and muscular excitability is greatly enfeebled by some diseases, *e.g.*, by anæmia, and in poisoning by lead, opium, or mercury. Much needless confusion has been introduced into this subject, by a statement persistently made by Duchenne, that the primary induction current acts especially on muscles, and the secondary induction current chiefly on the cutaneous nerves. The fact is that there is not any essential difference in action between the primary and secondary current, beyond one of density.

With reference to the action on the nervous system, it will be enough to mention one or two leading points. If a feeble current be directed to the head, it was, until recently, supposed that no current could go through the brain, and that it would travel round by the back of the scalp; but, one of the most certain discoveries in electro-therapeutics is, that it is feasible to affect the nerve centres immediately, and that by a galvanic current applied to the sides of the head or to the occiput, it is possible to influence the brain directly, and part of the current does undoubtedly pass through the brain. The clinical effects are worth noticing, for we can very materially affect the functions of the brain by a feeble galvanic current. A very moderate continuous galvanic current (5-8 cells) applied to the head will produce giddiness,

drowsiness, and in some people nausea. If the current be strong it may bring on serious symptoms and even convulsions. We must, therefore, be extremely cautious about applying a continuous galvanic current for any length of time to the head. On the whole, it may be said that galvanic treatment of the brain is of limited application, especially when we take into account the necessity of employing feeble currents, the impossibility of properly localising the current in the brain, while the parts most frequently diseased are those which are most deeply situated and least within reach. On the other hand, the spinal cord, on account of its elongated form and anatomical surroundings, offers itself much more accessibly for electric treatment, and, with moderate currents, it is undoubtedly possible to distinctly influence the cord directly, and to exercise a salutary power in several chronic diseases by modifying its conditions of nutrition. Again, a continuous galvanic current is the only single agent known that will excite all the nerves of special sense—those of vision, smell, hearing, and taste, in addition to the cutaneous nerves. A feeble electric current applied anywhere in the neighbourhood of the face will excite the *retina*, and the colour of the flash will depend upon the *strength* and direction of the current. The

optic phenomena are due to a direct action upon the retina, and not to a reflex influence from the fifth nerve, as is commonly believed. In making the experiment with regard to the *gustatory* nerves, if one of the electrodes be placed directly on the tongue, either an acid or alkaline taste is perceived. This was formerly supposed to be connected with the fact, that electricity decomposes saline fluids into acids and alkalies, and that the result was simply electrolysis of the saliva. This, however, is an error.. The effect of electricity on the tongue is not due to any electrolysis of the saliva, but is proved by a great many experiments to be a direct action on the physiological function of the nerve itself. In reference to the *auditory* nerve it appears to be proved that electric irritation is incapable of producing specific acoustic phenomena, and Brenner's startling assertions and theories, which have attracted some attention, have been satisfactorily refuted. Within the last few years we hear a good deal of the galvanisation of the *sympathetic* nerve, and it is believed by many to be possible to influence for good distant parts of the body by electric stimulation of the cervical sympathetic. Yet that this is an extravagant and unphysiological assumption is evident when we reflect that the cervical sympathetic, even if

definitely stimulated, could affect only a limited portion of the body in a limited way; that it is quite impossible to irritate the sympathetic apart from the adjoining nerves, *e.g.* vagus, laryngeal, and other nerves, and, as Cyon remarks, the fact simply is that we do not possess any means of producing in the living subject any definite good by direct galvanic irritation of the sympathetic nerve.

The last effect of electricity is on general nutrition, which is most unmistakeable; and Niemeyer, who is certainly not over credulous, speaks of the introduction of the continuous current into practice, as one of the most important advances of modern times. In the constant current, he says, we have a more powerful means of modifying the nutritive condition of parts deeply seated below the surface than in any other way.

Let us now look at the points of contrast between the two forms of electricity—the direct and the induced. What is loosely called the continuous current we use as a general rule in an interrupted manner; therefore the term "continuous" is not applicable to the mode in which we frequently use the direct or battery current. Secondly, "interrupted" is an erroneous term for the induced current; partly because in prac-

tice we frequently have occasion to interrupt the battery current, and partly because induced currents do not operate in virtue of their interruption, but because they are *instantaneous* currents. In the one form of apparatus, viz., a voltaic battery, the current is continuously evolved, and always runs in the same direction. The positive pole is the positive pole throughout, and the negative is always the negative. We therefore get chemical effects from this form of electricity; the poles being always of the same name, the proper constituents of a compound are liberated at their respective poles. In the other form of electricity, *i.e.*, induced electricity, on the contrary, we do not obtain considerable chemical effects. At every momentary interruption the current must run alternately in opposite directions; therefore as each pole is always changing its name, the chemical effects are neutralised. All voltaic batteries of any form furnish a large quantity of electricity, but of low tension, while all coil machines furnish a small quantity, but of high intensity. If the two poles of a battery are placed on the skin, they will produce a vivid sensation of heat in the skin, and if the poles are kept there sufficiently long, inflammation of the skin will be caused. The poles of the induction apparatus

excite a tingling sensation, but will not readily cause inflammation. This suggests a caution not to apply a continuous current too long on the skin. A galvanic current of moderate strength acts comparatively feebly on healthy muscles; the induction currents act powerfully on healthy muscles. We know that we can also affect the nerve-centres directly by a continuous galvanic current, but we cannot do so by induced electricity, unless it be very intense. The continuous current readily excites all the nerves of special sense, and the other does not. Lastly, the galvanic current causes that peculiar condition called electrotonus, but the induced current does not.

In order to obtain a clearer view of these points of contrast between the two kinds of current, we may sum them up in the following table:

Direct (constant; continuous: galvanic.)	*Induced (interrupted: faradic.)*
1. Continuously evolved, and current moves constantly in the same direction.	Momentary in origin & duration, rapid in succession, current moves alternately in opposite directions.
2. Possesses large quantity and low tension.	Small quantity and high tension.
3. Well-marked chemical, thermal, and electrolytic effects, on account of its greater *duration* and uniform *course*.	Chemical, thermal, and electrolytic effects feeble, on account of its short duration, and incessant change in direction.

4. Causes sensation of burning heat in the skin, and ultimately inflammation.	Tingles the cutaneous nerves, especially when the skin is dry, but does not readily cause inflammation.
5. Acts comparatively feebly on healthy muscle.	Acts powerfully on healthy muscle, by Du Bois Reymond's law, and because the *irruption* of the current into the muscle is abrupt.
6. Affects the nerve-centres directly.	Does not, except when very powerful.
7. Readily excites the nerves of special sense, particularly the retina.	Does not, except when very intense.
8. Causes electrotonus.	Does not, on account of the brief duration, and oscillations in intensity and direction.

LECTURE IV.

THERAPEUTIC USES OF *Galvanisation* (DIRECT CURRENT), AND OF *Faradisation* (INDUCED CURRENT)—GENERAL RULES FOR PRACTICE—BOTH THE DIRECT AND INDUCED CURRENT ARE ESSENTIAL TO SUCCESSFUL PRACTICE, BUT WE HAVE TO EXAMINE THE SPECIAL FUNCTIONS OF THE *Direct* AND *Induced* CURRENT—PRINCIPLES OF LOCAL ELECTRISATION (*i.e.*, GALVANISATION OR FARADISATION)—HOW TO LOCALISE THE CURRENT IN THE SKIN OR IN THE MUSCLES RESPECTIVELY—VALUE OF THE "*motor points*" ILLUSTRATED—APPLICATION OF ELECTRICITY TO DIAGNOSIS—MODE OF ACTION OF ELECTRISATION—CONCLUSION.

IN the last lecture we glanced at the physiological action of electricity on the nerves and muscles, and we shall now inquire what are the principles which should guide us in applying any form of electricity to the human body—in other words, the therapeutic uses of Galvanisation and Faradisation.

Although it must be admitted that our knowledge of electro-physiology is still very imperfect, and though we are still far from having an accurate basis for perfect clinical application, yet there are certain general rules which should

always be observed, and an infringement of which is followed frequently by injurious consequences to the patient. The first rule is, on no account employ too strong or too painful a current. It will be readily understood that not only is it injudicious to alarm the patient by painful shocks, but that, as a rule, moderate or feeble currents used for a short time will produce the best therapeutic results. With beginners especially there is a great tendency to overdo electric applica tions. On a previous occasion we saw that there were special dangers attending the application of the galvanic current to the head or face—in other words, over excitement of the nerves of special sense. With reference to the effect of inductional electricity, before you apply it to a patient it is well to use a simple test on your own body. Try the current on your own thumb muscles, and use, then, as the minimum strength on the patient that which will just produce contraction in your own muscles. You will thus run no risk of giving your patient a violent shock at the outset. The intensity of the current must be varied according to the resistances to be overcome, and will be regulated also by the organs to be acted upon, and by the effects sought to be obtained. Again, you should not apply electricity for too long a time, for it is far better to give a patient

much too little than a little too much, especially with the galvanic current; and you should remember that there is a very real source of danger in the excitability of nerves and muscles being exhausted by too strong a current. With induced currents the sittings should not be prolonged beyond a few minutes to each part, but if we wish to influence the vasomotor nerves, or effect electrolytic or other changes in nerve-nutrition by a galvanic current, *e.g.*, on the spinal cord, longer sittings are requisite. Again, you should not apply it too frequently; and the fourth rule is that, whenever possible, you should apply it locally. The mode in which electricity is but too often employed is simply absurd. Avoid subcutaneous bones, because the application of electricity to them is excessively painful. And lastly, in order to produce muscular excitation or contraction with induced electricity, use generally the primary current, for the simple reason that it is far less painful than the other, and not, as Duchenne mistakes, because it has any special action on the muscles.

In the next place we have to consider the special uses of the galvanic and of the faradic currents. It is agreed on all sides that both the induced and direct currents are essential to successful practice, and this leads us to exa-

mine what are the special functions of the direct and induced current, and these naturally depend upon the differences in their action, which were explained in the preceding lecture. We should, for example, use the direct current whenever we wish to excite the nerves of special sense, for the other form of electricity has very little action on them. If we wish to reduce a muscular spasm directly, use a moderately feeble continuous current; but it is certainly singular how obstinately a small, and in itself an insignificant spasm, when once firmly established, will so often refuse to yield to any attempt to overcome it, and, on the whole, spasm is much less amenable to treatment than paralysis. If we would produce chemical action, for instance, electrolysis of tumours, coagulation of blood, &c., we must use the galvanic current, for induction currents move in alternate directions, and therefore the poles constantly interchange, and so there is no continuous action going on. One of the most important applications of modern electricity, and one by which the greatest triumphs have been obtained, is in the relief of neuralgic affections, tic douloureux, sciatica, &c. Again, if we desire to influence the brain or spinal cord directly, we must resort to the galvanic current, for induced electricity has little or no effect, except violent irri-

tation, when intense, on the central nervous system. In speaking of constant or battery currents, it is needful to distinguish the effects produced at the moments of closing and opening the circuit from those arising during their continuous passage (*e.g.*, electrotonus and electrolysis). Induction shocks, *i.e.* the magneto-electric or electro-magnetic, are most generally used, first, to stimulate the cutaneous nerves; for instance, in cases of anæsthesia. The best method of doing so is to employ a moist electrode on the skin, and a wire-brush directed to the anæsthetic part. Another rational use of the induction current is to antagonise muscular spasm. Suppose there is contraction of the flexors of the arm, powerful induction currents applied to the extensors may antagonise the spasm, and in some cases put an end to it. As a general rule, by Du Bois Reymond's law, we use induced currents to stimulate muscles, but in some particular cases, when induction currents fail, we must adopt the interrupted galvanic current. Unfortunately we have no means of knowing beforehand whether a given paralysed muscle will react to the induction current or to the galvanic. Therefore, if we seek to find out as a clinical fact what is the relation of the muscles to electricity, we must simply try *both forms*. Observe which form acts best on

the muscles, and then use that form. There is as yet no scientific method of predicting in any particular class of affections which form of electricity will answer, but we know by experience that there are certain cases in which muscles will react to a galvanic current and not to a faradic; such as lead palsy, progressive muscular atrophy, facial palsy; traumatic paralysis, for instance, after dislocation, or nerve injury, and that peculiar paralysis that attacks the limbs of children, and benumbs the functions of nutrition, that wasting paralysis known as organic infantile paralysis. Those are the cases in which galvanic currents may stimulate the muscles, when the most powerful induction currents will often totally fail. It is not easy to understand, and it has never been explained, why a paralysed muscle will react to a lower degree of stimulus than will affect a healthy muscle; but with reference to the general explanation why the direct current sometimes acts on muscles more than the induction current, we must remember that induction currents are practically instantaneous, the trembler giving from 100 to 200 vibrations in a second, while the interruption of the galvanic current, for example, by dabbing with a sponge on the patient's body, does not at all approximate to that rapidity; and it has been conclusively

shown that the real cause of the difference in action of galvanic and induced currents on paralysed muscles is the *difference in their duration.* To sum up, we may tabulate the general uses of the two forms of current in the following manner:—

Direct.	*Induced.*
To excite the nerves of special sense.	To stimulate the cutaneous nerves.
To reduce muscular spasm directly.	To antagonise muscular spasm by exciting the opposing muscles.
To produce chemical and thermal changes, *e.g.* coagulation of blood, electrolysis, cautery.	
To stimulate muscles in certain cases.	To stimulate muscles in the majority of cases; and generally, to obtain energetic peripheral excitation.
To relieve neuralgic conditions.	
To affect the brain and spinal cord directly, especially the latter.	

Now, as to the local application of any form of electricity, let us clearly understand that the course of the electric currents is not straight along the skin or beneath it, but in curves, and the depth or convexity of the curve will depend on the strength of the current, and on the conductibility of the tissues it passes through. The *curves, of* course, must converge at each pole,

and in the right line which joins the two poles the density of the current will be greatest. The same quantity of electricity is circulating in the intermediate portions as at the points of application, only its density is very much less, because from the laws of propagation of currents in non-prismatic conductors (*e.g.* the animal tissues), the curves of electric force will diverge on every side in all directions, and therefore diminish in density. Rightly to understand the ramifications of an electric current in the body, the fundamental point to seize is this, that the mode of passage of electricity through the frame is totally different from its transmission through a homogeneous cylindrical conductor, such as a metallic wire. In the former case, the animal structures constitute a series of heterogeneous conductors, of irregular form and unequal conductibility. Accordingly, when the two poles of an instrument are placed upon any two points of the surface, the current starting from either pole divides into innumerable branches (forming "derived currents,") which ultimately converge to the other pole, the whole intervening space being traversed by electric curves. The intensity of the current in each conductor (muscle, nerve, &c.) is inversely proportional to its resistance, for, the greater the resistance, the less quantity of electricity will *pass in* a given time.

If we seek to relieve anæsthesia of the skin, it is plainly necessary to localise the current in the skin. If, on the contrary, we want to stimulate the muscles or nerve centres, it is requisite to facilitate the passage of the current through the skin. Now, the dry epidermis offers the greatest resistance to the electric current, consequently, in order to localise the current in the skin, both the epidermis and the electrodes must be perfectly dry. The electric streams passing through the natural apertures of the sebaceous and sweat-glands, excite any filaments of cutaneous nerves they meet with, but on passing into the better conducting muscles, the current spreads out uniformly and therefore attains in no place a density sufficient to excite muscular contraction. If, on the contrary, as in the majority of cases, we wish to excite the muscles or a deeper part, clearly we must cause the electricity to act deeply, without stimulating the cutaneous nerves, that is, without causing pain, consequently it is necessary thoroughly to moisten the epidermis with salt water, preferably warm, because salt water is a better conductor than pure water, and because warm liquids conduct electricity better than cold. The resistance of the skin being *thus* diminished and rendered almost equal *everywhere*, the whole of the electric current

traverses the epidermis without being split into a series of rays, and thus preserves a density sufficient to excite the muscles. From what has been already said in reference to density and intensity, it is evident that by altering the size of one or other of the electrodes we can vary the *density* of the current in a particular spot and so apportion it to the object desired, for the density of the current, and therefore its physiological action will be higher under whichever of the electrodes is relatively smaller than the other. Again, the nearer the electrodes are to each other the greater will be the density of the current in the interval between the poles, and on this principle a comparatively feeble current can be employed to excite a single muscle, whereas if the electrodes be widely separated, the current spreads out almost uniformly in every direction, and thus in no place reaches a sufficient density to provoke muscular contraction.

These are the simple principles of local electrisation, which are over and over again misapplied in practice. If one pole be put over the motor nerve and the other on the muscle, it is called "indirect" or "extramuscular" electrisation. The application of both poles on the muscle constitutes "direct" or "intramuscular" electrisation. There are certain points along the surface

of the body where muscles are more easily excited than at any other points. These are what are termed the "*motor points*" of the muscles. They were first recognised by Duchenne as clinical facts, first explained by Remak, and first represented in diagrams by Ziemssen. The points where you excite the muscles most easily are those where the motor nerves enter the muscles. It is possible, for example, to bring into action even the extensor indicis, though the deepest muscle in the arm, without exciting a single other muscle. It is easy to pick out every one of the four muscles of the ball of the thumb and show their individual action without engaging the others, and similarly with the interosseous muscles. If you wish to make an accurate diagnosis of muscular paralysis, it is requisite to know the points at which the muscles are most easily excited. But beside the special use of electricity in ascertaining what muscles are affected, there is another diagnostic application not resorted to as much as it ought to be; for example, in the distinction of feigned from real paralysis, or in the distinction of hysterical paralysis from real hemiplegia or paraplegia, and of central from peripheral paralysis. In central paralysis due to primary disease of the brain, *the excitability* of the muscles to induced elec-

tricity is not affected, but in peripheral paralysis the almost invariable rule is, that after a few days it is diminished. In examining muscles, we should be careful to distinguish the *excitability* (*i.e.*, the property of passing from a state of rest to one of activity) from the *contractility*, which is measured by the work the muscle is capable of effecting when it passes into the state of excitation, for one of these functions may be modified independently of the other. As a general rule, however, both of these properties suffer simultaneously, and clinically it is not always easy to study their modifications separately.

It is of some importance as a matter of diagnosis to be able to ascertain what state the structure of a muscle is in, whether it has undergone fatty degeneration or not, and an ingenious instrument called Duchenne's trocar has been constructed for this purpose. If this be introduced, say into the leg of a child, a little piece of the muscle is caught in the notch below, and you can examine it microscopically. Again, electricity has been applied in determining the functions of muscles, those for instance which give rise to the various expressions of laughter, disgust, &c.

In conclusion, a few words as to the mode in

which electricity is believed to act, a subject on which our knowledge is very limited. The general action of static or frictional electricity may be considered to be stimulating, and as it is not much used in medicine, we will pass it by. The effects of the galvanic current are complex, and not yet at all thoroughly understood. Its most important influence is certainly that of promoting nutrition and increasing the circulation of the blood in the part, and hence probably it acts mainly as a nutritive stimulant in that way. It also assists materially the natural osmotic processes constantly going on, and it certainly affects the natural nerve current and electromotive forces of the living body. It is easily understood that supposing the normal nerve current of a limb becomes deranged by disease, the passage of a continuous electric current can alter very materially the condition of the animal nerve current. Hence it is possible that in some cases of disease, electricity may act beneficially by restoring the perverted or by increasing the diminished natural nerve current of the limb. However that may be, its effect on nutrition is very striking. The mode of action of faradisation is better understood. For example, its beneficial effects in paralysis can *be explained* on certain principles such as these.

It is capable of physiologically stimulating nerves and muscles, and hence in case of lost or impaired functions, it will tend to restore them; for the longer a function is in abeyance, the more difficulty there is in renewing it. Secondly, it produces that salutary exercise of muscles, so essential to healthy nutrition; and thirdly, it increases the supply of arterial blood to the limb, and so promotes increase of tissue.

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